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beyond very short distances cross-over percentages do not increase in proportion to distance. The linkage group forms a means of holding genes together, however distant they may be from each other, so that, as one goes, all have a tendency to go. The linkage map will give us a diagrammatic view of the relations to each other of the genes composing a linkage system. It is based on the *shorter observed cross-over percentages,* or where longer distances are used, they must be first corrected for double and triple crossing-over. See in this connection the valuable Table II. of Haldane (1919) which provides a ready means of converting map distances into cross-over percentages or *vice versa,* and so of predicting undetermined linkage relations. It is based on a mathematical examination of the linkage system of the first chromosome of *Drosophila.* A table of linkage strengths will show us, without reference to distances involved, to what extent the movements in gametogenesis of one gene are correlated with those of any other gene. It is based on the *unmodified cross-over percentages observed,* whether the map distances involved are great or small. Linkage strengths can never exceed 50 on a scale of 50, 100 on a scale of 100, whereas map-distances may be extended indefinitely with the discovery of new genes.

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IS THERE LINKAGE BETWEEN THE GENES FOR YELLOW AND FOR BLACK IN MICE?

IN a recent number of this journal Dunn[1] has given data showing a deficiency of black young in a family of yellow mice.

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[1] AM. NAT., 53: 558–560, 1919.

Thus in a cross of two yellows, one of them probably heterozygous for both black and brown and the other for brown only, the offspring totalled fourteen yellow and four brown, the expectation being twelve yellow, three black and three brown. The yellow descendents of this mating when bred to browns are expected to give two yellows (one heterozygous for both black and brown and one heterozygous for brown only) to one black to one brown. The actual numbers obtained were eighteen yellow, one black, and ten brown, and the expected numbers fourteen yellow, seven black and seven brown. Dunn has summarized these data according to the percentage of young of each sort produced, as follows:

	Yellow	Black	Brown
Per cent. expected	66.6	16.6	16.6
Per cent. observed	62.0	3.4	34.5

In the total number of young observed, the chances are equal that the 16.6 per cent. expected black young might go as high as 30.8 per cent. or as low as 2.4 per cent. It is therefore apparent that neither the 3.4 per cent. black nor the 34.5 per cent. brown are significantly outside the limit of probable variation due to chance.

Although not including chance fluctuation as one of the three theories capable of explaining his observed facts, Dunn evidently feels the need for larger numbers of young before considering random sampling eliminated.

It is interesting however to see just what evidence there is in Dunn's data that black and yellow are linked. Apparently the only facts in support of this hypothesis is the deficiency of blacks and the slight excess of browns referred to. Significant evidence for the expected excess of yellows carrying both black and brown as compared with those carrying brown only is not obtained. Of seventeen such yellows tested, ten carried both black and brown and seven brown only—exact equality or 8.5 of each is the Mendelian expectancy. The excess of yellows carrying black and brown is 8.8 per cent. as against non-yellow browns of 17.9 per cent. The deficiency of yellow carrying brown only is 8.8 per cent. as against a deficiency of blacks of 13.3 per cent. The sum of the departures from the expected equality in *yellows* is 17.6 per cent., while in *non-yellows* it is 31.2 per cent., or almost twice as much. The discrepancies in the yellow individuals are even more within the possibility of chance fluctuation than those of the non-yellows.

Dunn states that linkage between Y and B "affords a satisfactory explanation of the observed facts in harmony with other cases of linkage." However, one of the essential points of linkage is that members of a multiple allelomorph series are linked to a given gene in the same degree. Cuénot,[2] Morgan,[3] Sturtevant,[4] and the writer,[5] have shown that the genes for yellow and for agouti in mice are allelomorphic. Many investigators, including Durham,[6] Detlefsen,[7] and the writer,[8, 9] have shown that agouti and black are not linked in inheritance—yet according to our present knowledge of linkage all genes in the same locus are equally linked with any other given gene, and these crosses should show linkage between agouti and black to a degree equal to that of linkage between black and yellow. Dunn has not emphasized this point sufficiently.

Furthermore, if there is any significance other than random sampling in the peculiar ratios reported, there is another possible explanation, not considered by Dunn, which avoids hypothecating linkage between yellow and black. If a lethal factor was closely linked with black in the particular family under consideration, and if this lethal was effective in a heterozygous condition in non-yellow mice—but not in yellow mice, the observed results would be explicable as follows:

Let Y equal yellow, y equal non-yellow.
B equal black, b equal brown.
L equal lethal, l equal normal.

Yy $\widehat{BL}$ $\widehat{bl}$ equals yellow heterozygous for black and lethal.
Forms gametes:

$$\left.\begin{array}{l} Y\widehat{BL} \\ y\widehat{BL} \\ Y\widehat{bl} \\ y\widehat{bl} \end{array}\right\}\text{commonly} \qquad\qquad \left.\begin{array}{l} Y\widehat{bL} \\ y\widehat{bL} \\ Y\widehat{Bl} \\ y\widehat{Bl} \end{array}\right\}\text{rarely}$$

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[2] *Archiv Zool. Exp. et Gen.* (4), Vol. 8, 1911.

[3] AM. NAT., 48, pp. 449–458, 1914.

[4] AM. NAT., 46, pp. 368–371, 1912.

[5] *Sci.*, N. S., 38, p. 205, 1913.

[6] *Jour. Genet.*, I, pp. 159–178, 1911.

[7] *Genetics*, 3, pp. 573–598, 1918.

[8] Carn. Inst. of Wash., No. 179, 1913.

[9] AM. NAT., 47, pp. 760–762, 1913.

Crossed with brown normal $yy\overset{\smile}{bl}\overset{\smile}{bl}$ such a yellow would give the following zygotes:

$$\left.\begin{array}{lll}
Yy & \overset{\frown}{BL}\ \overset{\frown}{bl}; & \text{Yellow heterozygous for black and lethal} \\
yy & \overset{\frown}{BL}\ \overset{\frown}{bl}; & \textit{Black lethal; dies*} \\
Yy & \overset{\frown}{bl}\ \overset{\frown}{bl}; & \text{Yellow carrying brown normal} \\
yy & \overset{\frown}{bl}\ \overset{\frown}{bl}; & \text{Brown normal}
\end{array}\right\}\ \textit{commonly.}$$

$$\left.\begin{array}{lll}
Yy & \overset{\frown}{bL}\ \overset{\frown}{bl}; & \text{Yellow carrying brown and lethal} \\
yy & \overset{\frown}{bL}\ \overset{\frown}{bl}; & \text{Brown lethal; dies*} \\
Yy & \overset{\frown}{Bl}\ \overset{\frown}{bl}; & \text{Yellow normal heterozygous for black} \\
yy & \overset{\frown}{Bl}\ \overset{\frown}{bl}; & \text{Black normal}
\end{array}\right\}\ \textit{rarely.}$$

The death of the rare brown lethal individual would not be noticed, for the common death of black lethals would leave a distinct excess of brown normals.

This hypothesis is capable of experimental test and involves a lethal mutation in an entirely new factor which presupposes no generality of the process in all yellows and agoutis; and simply assumes that yellow, when present, hampers the action of the lethal in much the same sort of way that it hampers the activity of the black forming factor in the skin and hair.

The above hypothesis is advanced simply as an additional possibility for test in case something more than chance fluctuation due to random sampling is involved.

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CREPIS—A PROMISING GENUS FOR GENETIC INVESTIGATIONS

To all who are familiar with the recent advances in our knowledge of heredity, which were made possible largely through the investigations of Morgan and others with the fly, *Drosophila melanogaster,* especially to those who have followed the development of the chromosome theory of heredity with its correlative theories of mutation and evolution, the urgent need of extensive corroborative evidence from other animals and plants must be forcibly clear. Although it appears inconceivable that the conclusions reached from the drosophila investigations are not applicable in all their essential features to all animals and plants,